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ABSTRACT

The formal operations skills and problem solving performance of 60 gifted girls (grades 4 through 6) were investigated. Ss were given Piagetian tasks which involved conservation of mass and weight, use of proportion, oscillation of the pendulum, and projection of shadows. Among findings were the following: (1) no relationship between IQ and either concrete operations (CO) or formal operations (FO) total scores; (2) positive association between age and total FO scores; (3) inverse correlation between time and IQ, CO, FO, and total Piagetian test score; and (4) precocity in 9 to 10 year old gifted girls on standardized intelligence scales and ability to solve Piagetian tasks quickly and correctly. Tables with statistical data are provided and descriptions of Piagetian tasks are appended. (SB)

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THE PERFORMANCE OF GIFTED UPPER ELEMENTARY SCHOOL GIRLS ON PIAGETIAN TASKS OF CONCRETE AND FORMAL OPERATIONS

by

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THE PERFORMANCE OF GIFTED UPPER ELEMENTARY SCHOOL GIRLS ON PIAGETIAN TASKS OF CONCRETE AND FORMAL OPERATIONS

Shirley Bekey, Ph.D.
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INTRODUCTION

In the psychological study of the intellectual capabilities of the gifted, two traditions have been preeminent: the psychometric and the Piagetian approaches. High IQ scores derived from a standardized intelligence test are related to precocious performance on Piagetian tasks of concrete and formal operations (Keating, 1973).

Piagetian theory states that the stage of formal operations (FO) does not generally appear until at least 11 years of age (Flavell, 1963). It is hypothesized that this developmental stage would appear prior to that age in gifted children with an IQ of 132 or higher, this group being in the upper 2% of scores on standardized intelligence tests (Keating, 1973).

Relatively few research studies have been conducted using Piagetian tasks with children of high intelligence. Keating (1973) compared average and gifted boys in the fifth and seventh grades using four Piagetian tasks. Results showed that gifted students at both grade levels had reached the stage of formal operations, whereas the average group did not show that ability. Sieber (1978) tested bright and average girls in grades five

through eight using five Piagetian tasks. Results indicated significant differences in performance between average and bright subjects, and more facility in FO in the older girls than in the younger groups. Neither study dealt with 8 to 12 year old gifted girls, all of whom had IQ scores of 132 or higher.

There is a need for research with young gifted children to discover at what age they are able to handle problems involving aspects of abstract reasoning, proportion, and hypothetical thinking, all of which suggest FO skills. In late adolescence, indications of formal reasoning occur in about 70 percent of individuals of average intelligence (Ross, 1975).

Variables

Eleven variables employed were as follows:

Concrete Operations (CO)	Conservation of Mass	(CO-1)
	Conservation of Volume	(CO-2)
	Composite CO Score	(CO-T)
Formal Operations (FO)	Use of Proportion	(FO-1)
	Oscillation of Pendulum	(FO-2)
	Projection of Shadows	(FO-3)
	Composite FO Score	(FO-T)
Total score on all five tasks		(PIAG-T)
IQ scores on Stanford-Binet Intelligence Scale		(SBIS)
Total time needed to complete all five tasks		(Time)
Chronological age		(Age)

Hypotheses

Simply stated, six research hypotheses indicated (1) no relationship between CO-T and SBIS, (2) positive relationship between FO-T and SBIS, (3) negative relationship between either CO-T or FO-T and Time, (4) positive association between either CO-T or FO-T and Age, (5) negative correlation between Time and SBIS, and (6) negative relationship between Time and Age.

Purposes

Three major purposes of this investigation were: (a) to ascertain differences in average performance level between one sample of Highly Gifted girls (HG) and a second subsample of Regularly Gifted girls (RG) as well as among subgroups in Grades 4, 5, and 6 on each of five tasks; (b) to estimate the percentage of girls at each grade level (age) who would reach a 75 percent performance criterion on each Piagetian task; and (c) to provide evidence regarding the tenability of each of the six research hypotheses with an underlying goal of determining at what age young gifted girls are able to engage in formal operations.

METHOD AND PROCEDURES

Research Sample

60 fourth- through sixth-grade girls were selected randomly from four elementary schools of the Los Angeles Unified School District. All girls had been identified for inclusion in the California State Mentally Gifted Minors Program because of having an IQ score of 132 or higher on the Stanford-Binet Intelligence Scale. IQ scores of girls classified as Regular Gifted ranged from 132 through 144; Highly Gifted girls had obtained scores of 145 or higher. These results were available to the researcher for comparison to Piagetian test scores. The sample included 19 fourth-, 20 fifth-, and 21 sixth-graders. At each grade level, approximately half the girls were Regular Gifted, and half Highly Gifted. They ranged in age from 8.5 to 12.1 years. Racial composition was as follows: 80% Caucasian, 15% Asian, and 5% Black. Written consent had been obtained from parents.

Instrumentation

The following Piagetian tasks were included:

1. Conservation of Mass was adapted from the protocol of Sieber (1978). This task tests the ability of the subject to ascertain that a piece of clay manipulated into different shapes maintains its same mass.

2. Conservation of Volume, described by Fogelman (1970), involves the realization that the volume of water does not change when clay molded into different shapes is dropped into two containers holding the same amount of water.

3. Use of Proportion was modified from the stickman task (Burney, 1974), and involves an understanding of ratio. The subject measured the height of each of two owls, one being two-thirds the size of the other, using jumbo-sized paper clips. Next, she measured the height of the smaller owl, using small paper clips, and was asked to determine the size of the larger owl without actually measuring it with the small paper clips [Figure 1].

4. Oscillation of the Pendulum was taken from Inhelder and Piaget (1958). Given a pair of pendulums mounted together for comparison, the subject was asked to determine whether the rate of swing changed when weights of different sizes and strings of different lengths were used [Figure 2].

5. Projection of Shadows, adapted from Inhelder and Piaget (1958), made use of three rings of different sizes placed between a light source at one end of the baseboard and a shadow board at the other end. While experimenting with the rings in various holes, the examinee observed what happened to the size of shadows and demonstrated her understanding of the principle involved [Figure 3].

Four points were allotted for each task, producing a possible total of twenty points. Each task ended with a "check question" to verify whether or not the subject understood the principle underlying the task. A professor of physics served as consultant for setting criteria for correct answers.

Test Administration Procedure

All testing was conducted individually by the investigator at each of the four schools included in the study. Testing time required between 18 and 55 minutes per subject. During the testing session the equipment was hidden under cloth drapes until time for its use. Subjects were told that they could use whatever time was necessary to determine their answers. The atmosphere was relaxed, and subjects were encouraged to enjoy their experimentation with test materials.

Data Analysis

Intercorrelations among measures, significance tests of differences between means (though statistically questionable because of truncated score distributions), and stepwise multiple regression analyses were calculated. The alpha level of significance was set at .05. Descriptive statistics are summarized in Tables 1 and 2. Table 3 portrays the proportion of girls who reached the 75 percent criterion level on each Piagetian task.

RESULTS

The following statistical findings occurred:

1. For all CO and FO measures, no significant differences existed between means of Highly Gifted and Regular Gifted subsamples or among means of subgroups categorized by grade level.

2. On both CO tasks and on two FO tasks (Pendulum and Shadows), at least 95 percent of gifted girls at each grade level

attained the 75 percent performance criterion. However, nearly all girls failed the Proportion task.

3. Zero-order correlation coefficients showed a negative relationship between Time and either total CO or total FO scores.

4. In forecasting either total CO or total FO scores from IQ scores, Time, and Age using stepwise regression analyses, Time was the most heavily weighted predictor. A strong negative relationship existed between Time and the total Piagetian test score ($p < .001$).

Hypotheses

Of six research hypotheses formulated, the first was tenable; the second, not sustained; the third, strongly supported; the fourth, upheld for FO but not upheld for CO; the fifth, sustained; and the sixth, not sustained.

DISCUSSION

Two circumstances reflected noticeable incongruities in findings: (a) the slight (though not statistically significant) tendency for gifted girls in the fourth grade to receive higher average scores on the CO tasks than those girls in the higher grades (b) the unanticipated difficulty level of the Proportion task.

Concrete Operations

Explanations for the slight superiority of fourth-grade girls over that of the fifth-or sixth-grade girls on the two CO tasks could be associated with differences in the expectations of subjects about the difficulty of test items. Possibly the younger girls were more attuned to the CO level than were the

older girls who appeared to be looking for greater complexity than was present -- a situation which Sieber (1978) has discussed. Older girls tended to suspect that something "tricky" was taking place rather than taking the questions at face value. This questioning attitude may well be a disadvantage for gifted children when given relatively simple tasks. By contrast, the younger girls had approached the tasks with a rather direct simplicity.

Formal Operations

At least 95 percent of gifted girls at each grade level met the 75 percent criterion of performance with respect to the Pendulum and Shadow tasks. However, in the entire sample, only two sixth-grade girls successfully solved the Proportion task. Possible explanations are as follows:

1. The existence of two substages within the development of the FO process (Inhelder & Piaget, 1958) would suggest that for the Proportion task, nearly all the subjects were at the early rather than advanced stage of formal operations, even though these girls were familiar with the concept of fractions. Possibly the ability to do proportional reasoning is achieved at the later stage of FO development, and the demands of the Proportion task were beyond the reasoning abilities available at the early stage. In general, children are able to perform proportional problems after the age of 14 to 15 years (Inhelder & Piaget, 1958).

2. The Pendulum and Shadow tasks involved trial-and-error manipulation, permitting use of a discovery method of learning

that was largely lacking in the measurement of the owls for the Proportion task. Also, the equipment for the easier tasks might have appeared to be more real and tangible than the abstraction involved in comparing the sizes of the two owls. Solution of the Proportion task would require an immediate realization that the concept of ratio (rather than addition) was required.

3. Perhaps the 2:3 proportion used for the relative sizes of the owls was confusing, and difficult to answer without paper and pencil. Possibly the proportion of 1:2 would have produced higher scores by reducing the complexity of the problem. In that event, the evidence might indicate that the Proportion problem presented in this study was unnecessarily difficult, preventing the girls from displaying their comprehension of the concept of ratio.

Another factor to consider is that the Shadow problem involves an implicit understanding of ratio, and every girl had solved that task successfully. If the Shadow task requires a level of thinking at the advanced FO stage, then all subjects would have attained that level of cognitive development. On the other hand, if the Shadow task is indicative of performance at the early FO stage, that conclusion could not be made.

SUMMARY

1. No relationship existed between IQ and either CO or FO total scores.

2. There was a positive association between age and total FO scores. Older girls demonstrated more formal operational skills.

3. There was an inverse correlation between Time and the following variables: IQ, CO, FO, and total Piagetian test score. Therefore the brighter the subject, the more rapidly she worked. Success on Piagetian tasks was related negatively to time required to complete them.

4. Most gifted girls of 9 or 10 years of age (perhaps 95 percent) can perform successfully on two or more tasks of formal operations. Therefore precocity is observed in test scores of standardized intelligence scales and in ability to solve Piagetian tasks quickly and correctly.

Table 1

Descriptive Statistics on Each Variable for the Subsamples of Regularly Gifted and of Highly Gifted Pupils and for the Total Sample

Variables	Regularly Gifted Pupils (n = 29)			Highly Gifted Pupils (n = 31)			All Gifted Pupils (n = 60)		
	M	SD	Range Low to High	M	SD	Range Low to High	M	SD	Range Low to High
1. CO-1	3.85	0.36	3-4	3.65	0.80	0-4	3.74	0.63	0-4
2. CO-2	3.69	0.54	2-4	3.77	0.50	2-4	3.73	0.52	2-4
3. FO-1	2.00	0.23	1-2.5	2.13	0.50	2-4	2.07	0.40	1-4
4. FO-2	4.00	0.00	4-4	3.94	0.36	2-4	3.97	0.26	2-4
5. FO-3	3.76	0.39	3-4	3.94	0.25	3-4	3.85	0.34	3-4
6. CO-T	7.53	0.73	6-8	7.42	1.06	3-8	7.48	0.91	3-8
7. FO-T	9.76	0.48	8.5-10	10.00	0.68	8-12	9.88	0.60	8-12
8. PIAG-T	17.29	0.80	16-18	17.43	1.24	13-20	17.37	1.04	13-20
9. SBIS	136.14	3.53	132-142	154.81	8.61	145-185	145.78	11.49	132-185
10. Time	35.93	7.13	23-55	29.68	6.37	18-47	32.70	7.40	18-55
11. Age	10.48	0.95	8.68-11.94	10.36	0.93	8.73-12.08	10.42	0.93	8.68-12.08

Table 2

Descriptive Statistics on Each Variable for Subgroups of Gifted Pupils (Regularly Gifted and Highly Gifted) at Each of Three Grade Levels

Variables	Fourth-Grade Pupils (n = 19)			Fifth-Grade Pupils (n = 20)			Sixth-Grade Pupils (n = 21)		
	M	SD	Range (Low to High)	M	SD	Range (Low to High)	M	SD	Range (Low to High)
1. CO-1	3.97	0.12	3.5-4	3.45	0.95	0-4	3.81	0.40	3-4
2. CO-2	3.90	0.32	3-4	3.65	0.59	2-4	3.67	0.58	2-4
3. FO-1	1.97	0.26	1-2.5	2.00	0.00	2-2	2.21	0.60	2-4
4. FO-2	3.90	0.46	2-4	4.00	0.00	4-4	4.00	0.00	4-4
5. FO-3	3.87	0.33	3-4	3.98	0.11	3.5-4	3.71	0.44	3-4
6. CO-T	7.87	0.33	7-8	7.10	1.25	3-8	7.48	0.75	6-8
7. FO-T	9.74	0.63	8-10	9.98	0.11	9.5-10	9.93	0.81	9-12
8. PIAG-T	17.61	0.66	16-18	17.08	1.24	13-18	17.40	1.10	16-20
9. SBIS	145.11	10.22	132-164	144.80	10.64	133-167	147.33	13.58	132-185
10. Time	34.32	6.51	20-45	32.05	6.93	18-45	31.86	8.60	18-55
11. Age	9.28	0.28	8.68-9.76	10.47	0.30	9.98-11.02	11.40	0.39	10.74-12.08

Table 3

Numbers and Percentages (in Parentheses) of Pupils at Each of Three Grade Levels Who Attained a 75 Percent Criterion Level (3 out of 4 Possible Points) on Each of Five Piagetian Tasks

Grade Level	Number of Subjects	Piagetian Tasks				
		CO-1 Conservation of Mass	CO-2 Conservation of Volume	FO-1 Use of Proportion	FO-2 Oscillation of the Pendulum	FO-3 Projection of Shadows
Four	19	19 (100%)	19 (100%)	0 (0%)	18 (95%)	19 (100%)
Five	20	19 (95%)	19 (95%)	0 (0%)	20 (100%)	20 (100%)
Six	21	21 (100%)	20 (95%)	2 (10%)	21 (100%)	21 (100%)
Total Group	60	59 (98%)	58 (97%)	2 (3%)	59 (98%)	60 (100%)

Note: All percentages have been rounded to whole numbers.

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APPENDICES

DESCRIPTION OF PIAGETIAN TASKS

Piagetian tasks used in this study were based on the work of Ball and Sayre (1972), Burney (1974), Fogelman (1970), Inhelder and Piaget (1958), Keating (1973), and Sieber (1978).

Conservation of Mass (CO-1)

Two balls of colored playdough were formed prior to the experiment, each ball weighing two ounces (56.70 g).

Instructions were as follows:

1. Here are two balls of playdough which are the same size and equal in weight. Do they contain the same amount of playdough? (Examiner gives correct answer, if necessary.)
2. I am squashing one ball into a sausage shape. Now do they both contain the same amount of playdough?
3. Why?
4. Now I'll squash the other ball into a flat pancake. Do the pancake and sausage contain the same amount of playdough?

Conservation of Volume (CO-2)

Two eight-ounce (236.56 ml) measuring cups were filled with five ounces (141.75 ml) of water prior to the beginning of the experiment. Two balls of playdough weighing two ounces (56.70 g) each were used.

Instructions were as follows:

1. Here are two balls of equal size and two containers. Each measuring cup holds five ounces of water. If I put one ball into the water, what will happen to the water level? (Examiner waits for answer, then places ball into one container.)

2. Now if I put the other ball into the other container, what do you think would happen to the water level? Would it go to the same level, or possibly a different level? (Examiner waits for answer, then places second ball into the second container.)
3. Suppose I change one ball into a sausage shape. What will happen when I put it into the water? Will the water level be the same as before, or different? Why?
4. Suppose I take some of the playdough from one ball and stick it onto the other ball, then put each ball into a container of water. What will happen to the water level in each bowl? (Examiner waits for answer before placing balls.)

Use of Proportion (FO-1)

Two owls had been drawn on opposite sides of a sheet of heavy white posterboard. Dimensions of the small owl were eight inches (20.32 cm) in height and 7.33 inches (18.62 cm) in width. The height of the large owl was 12 inches (30.48 cm) and its width was 11 inches (27.94 cm).

Instructions were as follows:

1. Here are two owls of different sizes and a string of jumbo-sized paper clips. If you use them like a ruler to measure the small owl, how many clips do you need? Measure his height from top to bottom. (Wait for reply.) Now turn the picture over and measure the large owl. How many clips do you need? (Correct answers: four and six jumbo paper clips.)

2. Here is a set of ordinary small paper clips. How many do you need to measure the height of the small owl? (Wait for answer.) Without turning the picture over this time, how many of these small paper clips would you need for the height of the large owl? Take your time to figure it out. (To help the child visualize the problem, the examiner repeats again the number of clips needed up to this point.) (Correct answers: six and nine small clips.)
3. How did you decide how many you would need for the big owl?
4. Suppose you had two huge paper clips that were half the size of the small owl. How many would you need for the large owl? (Correct answers: two and three huge paper clips.)

Oscillation of the Pendulum (FO-2)

Small metal fishing weights were assembled and could be attached to wires of various lengths. The weights were approximately elliptical in shape and included pairs of the following sizes: one ounce (28.35 g), three ounces (85.05 g), and six ounces (170.10 g). Weights were hung on wires from two eye-screws on a horizontal metal arm which was attached to a vertical post.

Instructions were as follows:

1. Have you ever seen anything like this? It is called a pendulum. Here are weights of different sizes and wires of different lengths. First, I'll take the large weights. I'll hold them up in the air and let them go at the same time. Notice the speed of their swing. Do they swing at the same speed or at different speeds? (Wait for answer.) Now I'll

lift them up higher. Do they still swing at the same speed?

2. Now here are weights of the same size which I'll place on wires of different lengths. When they are released, do they swing at the same speed or at different speeds? (Wait for reply.) Now let's try weights of different sizes placed on wires of the same length. Do they swing together or at different speeds?
3. What have you noticed about the swing of the two pendulums? When do they swing together at the same speed, and when do they swing at different speeds?
4. Now can you tell me what would happen if we used weights of different sizes:
   a. with wires of equal lengths? (An example is given.)
   b. with wires of different lengths? (An example is given.)

Projection of Shadows (FO-3)

Equipment for this task was elaborate and included several separate components. Three heavy black metal rings were sized as follows: one inch (2.54 cm), two inches (5.08 cm), and three inches (7.62 cm) in diameter. A low intensity lamp produced a small beam of light which was narrowed by passing through a hole in a solid cover over the light source. This was projected onto a shadow-board which had been coated with luminous white paint, making it possible for the shadow to be seen even in a fairly well-lit room. Six holes in the baseboard were spaced three inches (7.62 cm) apart, the first hole being three inches (7.62 cm) from the light source. The depth of each hole was approximately one inch (2.54 cm).

Instructions were as follows:

1. This equipment includes various parts. Here are three metal rings which are one inch, two inches, and three inches across. The light is at one end, and the shadow-board at the other end. All of the holes in the baseboard are three inches apart. Now you can experiment with placing the rings in different holes. As you play with them, notice the size of the shadow on the shadow-board. When you are ready, put the one-inch ring here, and the three-inch ring there; then reverse them. What happened to the size of the shadows?
2. Suppose you wanted to make shadows of equal size on the shadow-board, using all three rings. Try moving the rings around in such a way as to produce just one shadow. Can you do that?
3. Is the distance from the light important? Why?
4. Let's pretend that we could stretch out this baseboard to make it longer, putting the shadow-board at the far end. We would add more holes in the baseboard. Now suppose you had a four-inch ring and wanted the shadows of all four metal rings to overlap on the shadow-board. Where would you put that four-inch ring?

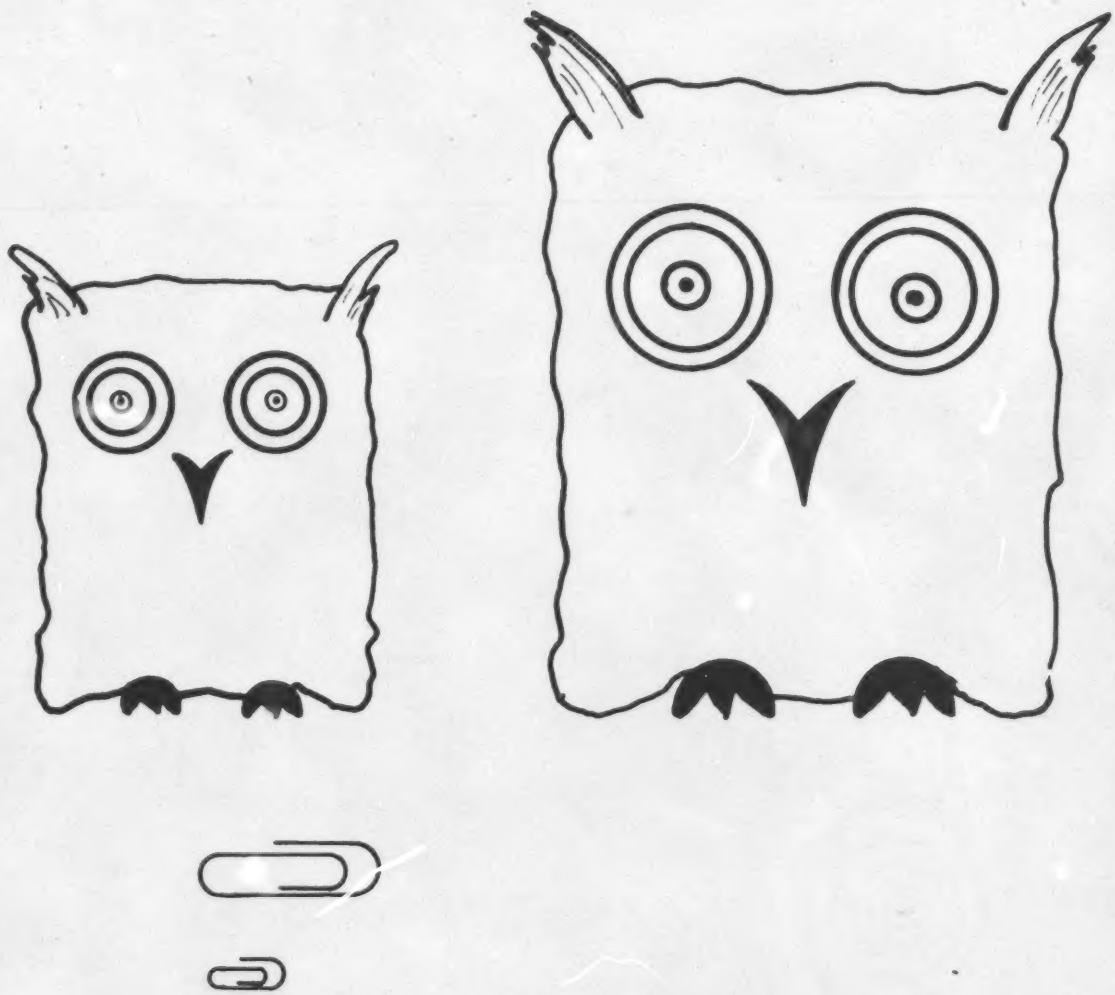

Figure 1. Sketch of equipment used for FO-1, Proportion Task

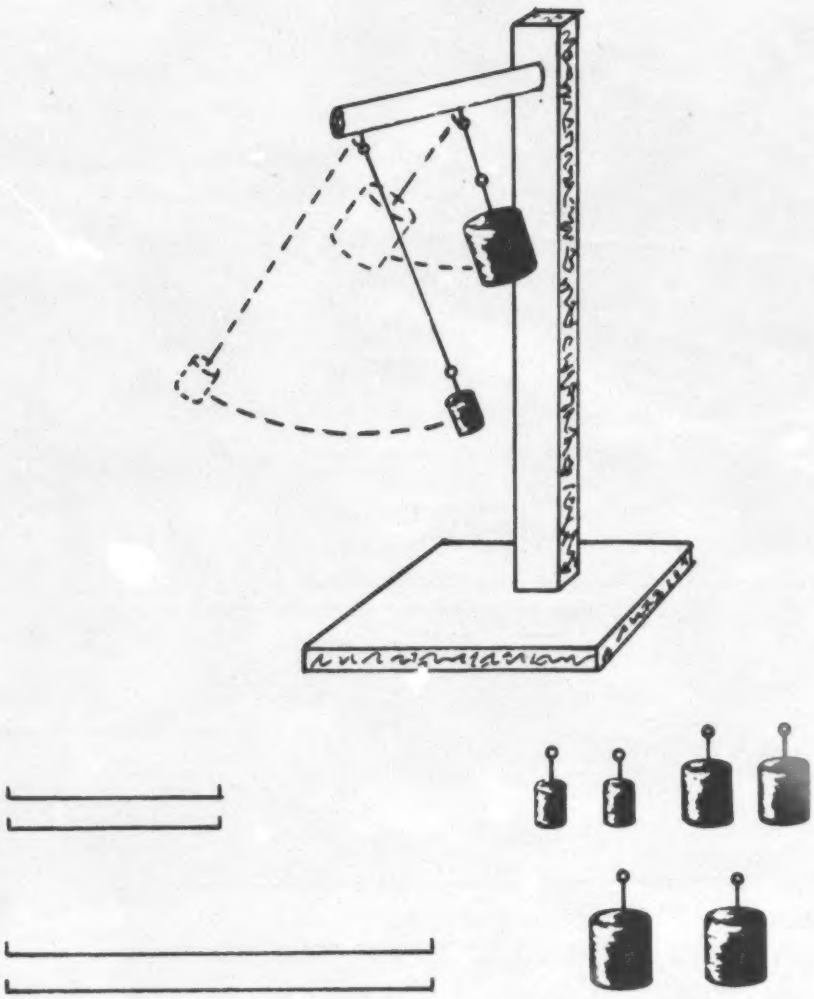

Figure 2. Sketch of equipment used for FO-2, Pendulum Task

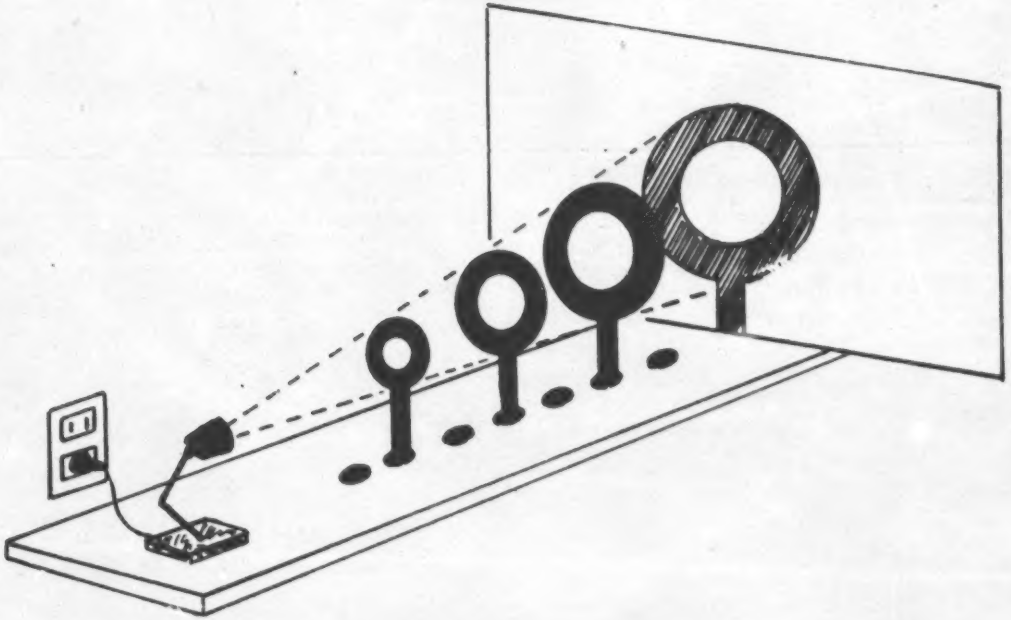

Figure 3. Sketch of equipment used for FO-3, Projection of Shadows Task

Specifications for Equipment

Portability

All equipment was built to allow for disassembling and fitting into a suitcase for transportation between schools.

Durability

Equipment was designed using heavy-duty materials so that the wear-and-tear of normal use by children would not affect the condition of the experimental components. All wooden parts were varnished.

Visual Appeal

Materials were used which were colorful and attractive. It was reasoned that the girls would be more motivated to solve problems if the equipment were visually appealing and professionally designed. Great care had been taken in the preparation of materials, and the equipment was professionally built by a skilled engineer.